PB81-152050

Particle Size Variation Effects on Landfilled Solid Waste: Cold Climate Studies

Thomas, Dean and Hoskins, Inc.
Great Falls, MT

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Feb 81

U.S. Department of Commerce
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TECHNICAL REPORT DATA
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1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/ 2-81-018		PB81 152050

4. TITLE AND SUBTITLE	5. REPORT DATE
PARTICLE SIZE VARIATION EFFECTS ON LANDFILLED SOLID WASTE: COLD CLIMATE STUDIES	February 1981 Issuing Date.
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
L. David Heckler	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Thomas, Dean & Hoskins, Inc. Great Falls, Montana 59405	1DC618 (MS 2.9)
	11. CONTRACT/GRANT NO.
	R-805012
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Municipal Environmental Research Laboratory--Cin., OH Office of Research and Development U. S. Environmental Protection Agency Cincinnati, Ohio 45268	Final (July 1978-July 1980)
	14. SPONSORING AGENCY CODE
	EPA/600/14

15. SUPPLEMENTARY NOTES
Project Officer - Richard A. Carnes, (513)684-4303

16. ABSTRACT

This research program was initiated with the overall objective of determining the effects of milled refuse particle size on landfilled solid waste.

Four experimental test plots were constructed using four different particle size distributions. Each pit containing a specified milled refuse particle size was evaluated in an attempt to correlate particle size with different parameters. The parameters under study were: wind displacement of milled refuse; differential settlement of compacted milled refuse; and attraction of vectors, rodents, birds and wildlife to the milled refuse.

Data was collected over a period of twenty months. Particle size distribution curves were developed herein for the milled refuse used. Four breakdowns of the composition of the raw solid waste prior to milling were included. Moisture content and field density test results were shown herein. Project results on the parameters mentioned above were included in this report. The Report was submitted in fulfillment of Grant R-805012 by the Montana State Department of Health and Environmental Sciences under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from July 25, 1978 to July 25, 1980.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Municipal Solid Waste, Landfill, Particle Size, Shredders, Cold Climate, Milled Refuse, Wind Displacement		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Public Distribution	Unclassified	
	20. SECURITY CLASS (This page)	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

PB81-152050

EPA-600/2-81-018
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by

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Grant No. R805012

Project Officer:

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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
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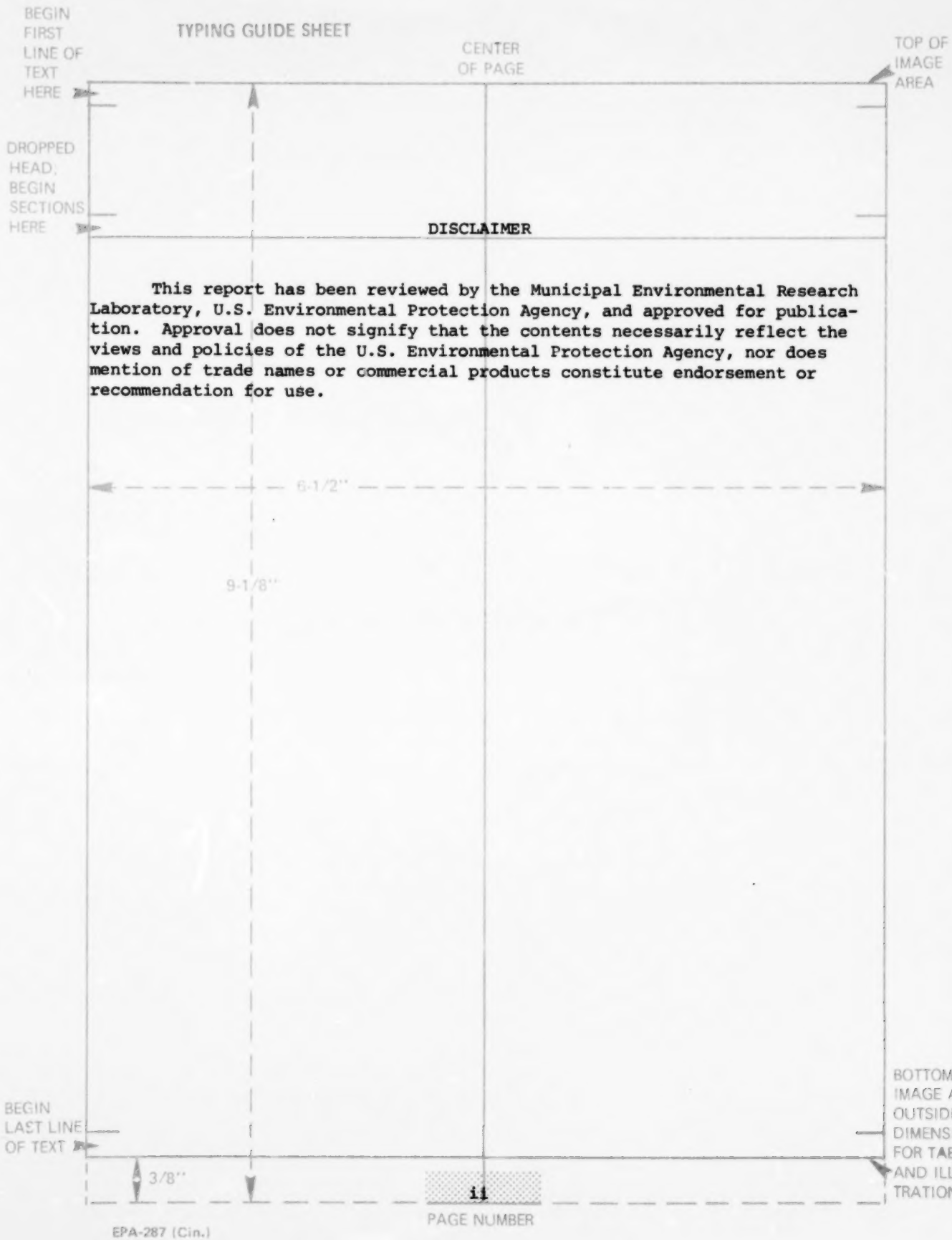
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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This research program was initiated with the overall objective of determining the effects of milled refuse particle size on landfilled solid waste.

Four experimental test plots were constructed using four different particle size distributions. Each pit containing a specified milled refuse particle size was evaluated in an attempt to correlate particle size with different parameters. The parameters under study were: wind displacement of milled refuse; differential settlement of compacted milled refuse; and attraction of vectors, rodents, birds and wildlife to the milled refuse.

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Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

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SECTION 1

INTRODUCTION

NEED FOR DESIGN PARAMETERS

Design criteria is inadequate or totally unavailable, to date, for correlating milled refuse particle size with wind displacement problems, settlement differentials, vector problems, etc. This lack of design criteria or operational parameters could have a detrimental effect on future milled refuse operations. States need more detailed data to establish acceptable parameters for operation and maintenance of shredding facilities. They also need more detailed data to adequately adopt proper regulations governing the disposal of milled refuse. Some states are adopting regulations that define particle size limitations without any proven data to substantiate these limitations. Reliable design criteria is needed to relate the effects of particle size on operational and esthetic variables.

PURPOSE OF PROJECT

The purpose of the project was to evaluate the following variables:

1. The effect of wind velocities on the displacement of milled refuse.

2. The amount of differential settlement within each test pit.

3. The presence or absence of vectors, rodents, birds, and wildlife at each pit.

4. Any observations of additional parameters that could be correlated with particle size were noted throughout the project period.

PARTICIPANTS IN STUDY

This project was funded by a research grant through the Solid and Hazardous Waste Research Division of the Municipal Environmental Research Laboratory of the Environmental Protection Agency and by the Solid Waste Management Bureau of the Montana State Department of Health and Environmental Sciences.

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This project was undertaken by the Montana Department of Health and Environmental Sciences in cooperation with the City of Great Falls. The firm of Thomas, Dean & Hoskins, Inc., of Great Falls, Montana, was utilized to provide the consulting engineering services required. The City of Great Falls refuse shredder was used to produce the different particle sizes of refuse for placement in test pits.
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SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were based on the findings of this study. If wind in an area exceeds 10 mph on a regular basis, as measured by the U.S. Weather Service as the "fastest observed one-minute sustained wind", then particle size of milled refuse becomes important. The smaller the particle size of the milled refuse, the lower the weight of the material that will be displaced by the wind.

Milled refuse material compacted to a density of 1,000 pounds per cubic yard does not settle or deteriorate at a rapid rate during the first one and one-half years. There does not appear to be any difference in the settling rate of milled refuse milled to different particle sizes. A small particle size material does not deteriorate or settle any more or less than a large particle size material in well compacted milled refuse over a one and one-half year period in areas and climates similar to that of Great Falls, Montana. Settling rates may vary over longer periods of time although the length of this project period limited that determination.

There does not appear to be any correlation between particle size of milled refuse and the attraction of flies, mice or birds in a well compacted milled refuse. A scum or surface bonding layer develops on milled refuse within six months of placement. This top surface deteriorates as well as bonds together and this deterioration may help to curb fly, rodent and bird activity.

In a well compacted milled refuse landfill the surface of the material is not displaced by wind to a great degree and this allows the scum layer to develop quite rapidly. This scum layer does act as a deterrent to wind displacement of the refuse and to fly and bird activity.

When proposing placement of milled refuse at a landfill site without daily cover, the following should be considered:

1. Mill the refuse to a maximum particle size where 70 percent of the milled material passes a two and one-half inch sieve or screen.

2. Compact the refuse to a density of 1,000 pounds per cubic yard or more.

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SECTION 3

EXPERIMENTAL WORK

PROCEDURAL REQUIREMENTS FOR STUDY

The United States Environmental Protection Agency reviewed and approved the methods and procedures followed to develop the research data needed. Project work was not initiated until the U.S. Environmental Protection Agency, Montana State Department of Health & Environmental Sciences, and Thomas, Dean & Hoskins, Inc., were all in agreement as to the methods and procedures that would be followed to complete the research work.

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In general, the project was to include four test plots or holes with dimensions 20* feet wide, by 35 feet long, by 6 feet deep excavated in the ground. Each test plot was to be filled with compacted refuse of a specific particle size. The milled refuse in the first test pit was proposed to ideally have 70 percent passing a two inch particle size, the second pit, 70 percent passing a four inch particle size, the third, 70 percent passing a six inch particle size, and the fourth pit, 70 percent passing an eight inch particle size. The test plots were to be located end to end with the long side of the four pits facing the prevailing southwest winds. These test pits were to be located in such a configuration and at a location that would be unobstructed in regard to the prevailing winds.

Following completion of the installation of the refuse in the pits, each pit was to be enclosed with one-half inch mesh fencing.

Monitoring data over a two year period was to provide information on wind displacement and settlement of the differing sizes of milled refuse. It also was to provide a correlation between vectors, rodents, birds and wildlife attraction to the varying particle size of milled refuse.

FIELD CONSTRUCTION OF TEST PITS

On August 18, 1978, Thomas, Dean & Hoskins, Inc., was given the go-ahead to initiate the project work required for the study.

The site selected for construction of the test pits was located on a hillside one quarter mile east of the existing City of Great Falls landfill site. This location was selected because the wind blows across the site

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unobstructed by any physical features such as trees, buildings, etc. The haul distance to the test site was approximately equal to that required to get to the City landfill site from the City owned pulverizer facility.

Four test pits were excavated with approximate dimensions 21' x 36' x 6' deep. Each test pit was separated from the adjacent pit by 8 feet of undisturbed soil.

The new test pits were constructed using a Caterpillar Traxcavator, Model 977, with a 2-3/4 cubic yard loader attachment. A small John Deere backhoe was used to shape up the edges of the pits and help level out the bottom of the pits. To get the front-end loader in and out of the pit, a steep ramp was excavated on one side of the pit to allow for access in and out.

The soil in this area was a heavy clay type material with some silt. It was extremely hard when dry. There was some moisture in the soil and following completion of excavation of the pits, the sidewalls were in excellent shape. However, as soon as the soil dried from exposure to air, the clay material shrank somewhat and allowed some spalling to occur on the sidewalls of the pits. Following excavation of the pits, wood forms were installed to the exact dimensions of 20 feet wide by 35 feet long inside the excavated holes. These forms prevented the spalled material from falling into the actual test pit area. The forms were constructed of 5/8" plywood, 5-1/2 feet long so that the finished form wall was approximately 6 inches below the surface of the ground following completion of the installation. The forms were reinforced with 2" x 4" structural framing and the bottom of the form walls were staked to the subgrade material to prevent movement of the forms. Tops of the forms were also staked into the sidewalls of the pit to help keep the forms from being knocked out of position. It was found that it was better to leave the forms nailed lightly so that should a wall cave, it would just displace one or two panels of the plywood instead of knocking the whole sidewall down. This worked well as there were some cases where some of the sidewalls did cave against the plywood sidewalls displacing one or two panels. It was fairly easy then to remove the spalled off dirt from the pit and replace the plywood forms with a minimum amount of work.

At the location where the access ramp was installed, the plywood forms were not installed until after the front-end loader (Traxcavator) was driven down into the pit prior to placement of the refuse. Once the Traxcavator was located in the test pit, the wood sidewalls were installed at the ramp to seal off the entire pit. After the front-end loader was in the pit, the only way out of the pit was to completely fill the pit with compacted refuse to the top of the ground surface. The wooden side forms were installed in the first two pits and not in the last two pits until after completion of the installation of the refuse in the first two pits. The reason being that if caving did occur in the third and fourth pits while the refuse placement operation was being done in the first two pits, it would be easier to clean out the soil prior to placement of the side forms. The carpenter at all times was able to stay ahead of the placement operation of the refuse in the preceding pits so there were no delays caused by the carpenter falling behind in his end of the work.

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Placement of the refuse in the pits was not difficult in itself, although the coordination of the operation proved to be the biggest concern of the project.

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HISTORY OF SHREDDING FACILITY

In the fall of 1973, a solid waste reduction plant was completed in Great Falls. It has since closed down due to the high cost of operation. During 1979, the City of Great Falls decided to return to a sanitary landfill type of operation.

This plant was constructed to grind all domestic refuse from this area. Milled refuse was hauled in 65 cubic yard transfer trailers to the landfill disposal site located north of Great Falls. The solid waste reduction plant was constructed with two Heil grinding mills; one of 20 ton per hour capacity, and one of 15 ton per hour capacity. These Heil mills are vertical shaft type shredders.

This shredding facility also included a magnetic separator unit installed on the outlet conveyor for removal of ferrous metals from the milled refuse. Since the value of reclaimed ferrous metals increased and decreased with time, the reclaimed metal was stockpiled until the price made it feasible to ship the material from Great Falls to a steel mill. At the time that this project was initiated, the magnetic separator was not in operation to separate the ferrous metal from the milled refuse. Therefore, the milled ferrous metal material was included in the refuse placed in the test pits.

METHODS AND EQUIPMENT

Weigh scales at the waste reduction plant were used to weigh all incoming refuse and all milled refuse prior to disposal. All the refuse delivered to the test pits was weighed on these existing scales.

It was proposed that the mills would be adjusted to produce a particle size material that would have 70 percent passing a two inch, four inch, six inch, and eight inch sieve. The material milled to each particle size was to be installed in each of the four test pits. A particle size analysis unit was designed and fabricated to accurately measure the milled refuse particle size to determine the actual gradation of the material. The sieve unit designed screened out particle sizes of dimensions 1/2 inch, 1 inch, 2 inch, 4 inch, 6 inch, and 8 inch.

The sieve unit consisted of two 13.5 foot circular trommel units, 22 inches in diameter with a support frame. Each of the two cylindrical units contained three different screens or sieve sizes. Two trommel units were required to process the six different mesh sizes required. They were designed to be turned by hand from one end after the refuse was placed in that end of the trommel. The upper end of the trommel frame was raised above the floor to allow particle flow from one end to the other. The refuse was placed in the trommel unit. As the trommel was turned, the refuse tumbled down to the

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second screen past the third screen and out the end of the trommel unit onto the floor. At this point, the refuse was collected off the floor and rerun through the second trommel unit where it was sieved to the 4 inch, 6 inch and 8 inch particle sizes with anything larger than 8 inch passing out the end on to the floor. In this way, it was possible to run a sieve analysis on six different particle sizes and weigh each particle size to determine the amount or weight of each particle size. In order for the refuse to tumble and flow through the trommel unit, it was necessary to raise the one end of the trommel 13 inches off the floor on the upper end. The refuse tumbled on one sieve long enough to allow all of that particle size of material to discharge onto the floor below that sieve before passing on to the next sieve size. As the refuse tumbled through the trommel, each particle size of material was collected on a plastic sheet properly located under the sieve. Each particle size of refuse was then collected and weighed to determine the amount of that particle size.

The trommel was supported on rubber wheels that rotated on the steel frame. Steel handles extending from the upper end of the trommel were used to rotate the unit. The speed of rotation was determined by observation. Rotational speed was ample when the refuse would tumble similar to the way it does in a clothes dryer.

The sieve analyses were completed very effectively using this trommel for determining the gradation of the refuse.

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The milled refuse for placement in the first pit was obtained without changing the hammer configuration in use at the mill at the time of placement. A problem existed with trying to grind shredded refuse to a consistent particle size. Hammer mills like those installed at the Great Falls facility tend to wear on a day-to-day basis. As the hammer wear increased, the particle size increased. So it was important that once the milling operation began for one pit, it continued uniterrupted until the placement operation was complete. The milled refuse was hauled to the site, stockpiled, placed, and compacted in the pits trying to keep delays at a minimum to maintain the most uniform size material at the mill. Following completion of the placement operations in each pit, a decision was made to determine if new hammers were to be installed to try and decrease the size of the material, or whether to continue using the hammers since normal wear caused an increase in particle size. In the end, the goal was to have approximately one pit with 2 inch, one with 4 inch, one with 6 inch, and one with 8 inch particle sizes of material.

Milled refuse was hauled to the pit in 65 cubic yard transfer trailers carrying a pay load of approximately 30,000 to 32,000 pounds per load. Five to six loads per pit were required to produce the density needed. The pulverized material was compacted into the 65 cubic yard transfer trailer at the pulverizer facility. The compactor unit that inserted this material into the truck did so to obtain a wet density of approximately 500 pounds per cubic yard.

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For each 65 cubic yard load of refuse that was milled for placement in the test pit, one composite sieve sample was determined and one moisture

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content was determined for that load. To get the samples for these tests, a 30 gallon refuse container was placed underneath the bottom of the conveyor belt as the refuse tumbled off the conveyor belt into the compactor unit prior to compaction into the transfer trailer. The 30 gallon refuse container was partially filled each time a sample was taken to allow for a composite sample from each 65 cubic yard load. The transfer trailer was moved forward five or six feet to allow for access to the front of the compactor unit. The 30 gallon sample container was then placed in the compactor and filled with milled refuse as it tumbled down from the discharge conveyor belt. This was the most accurate way of sampling the refuse since you would get small particles and large particles falling into the container. The moisture samples were collected in plastic bags and dried in the ovens at our laboratory following the day's run.

One sieve analysis and one moisture test were performed on each composite sample taken from each 65 cubic yard load that was hauled to the test pit site. See Table A-2 of this report for lab test results.

When the 65 cubic yard transfer trailer was completely filled, it was then weighed and sent to the test pit site area. The refuse was then stockpiled at the site. A John Deere backhoe-loader was used to pick up the refuse and place it into the specified pit. Once the refuse was discharged into the pit, the backhoe was used to spread the refuse to a uniform depth. Then the Traxcavator located in the bottom of the pit was used to drive over the material and compact it to the required density.

Placement of the refuse depended on many operations. The City pulverizer experienced some breakdowns which stopped production of the milled refuse and subsequently shut down the placement of the refuse in the pits. Also, there were equipment shutdowns that occurred with the backhoe and dozer equipment at the test pit site. This slowed down the refuse placement operation. Extremely windy weather, or rain, or snow conditions sometimes shut down the placement operation. Therefore, an attempt was made to get all of the material stockpiled at the site placed in the pits and compacted prior to leaving each night. Any material left overnight was subject to displacement by the wind when the weather deteriorated during the night. Weather conditions did not cause any real problems as it was usually possible to place the material in the pits prior to shutting down for the night. The few times the material did not get placed in the pits due to equipment breakdowns, the wind did not blow so the material was not displaced from the area.

In the Appendix of this report are curves indicating the different results of the sieve analysis for each pit. See Figures A-2 through A-5. This curve data indicates the variation in the particle sizes within each pit. There was a considerable range of variation due to hammer wear in the mills themselves over the period while the refuse was being placed in the pits. It usually took from two to three days of work to get one pit completely filled. In regard to displacement of the refuse caused by the wind, it was determined that the most important lift of refuse placed was the last lift, or the top lift on each pit. If this top lift was placed such that the actual particle size varied from pit to pit, then this indicated what effect the wind had on different particle sizes. An attempt was made to obtain a uniform particle

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size for each pit. This proved impossible due to the wear limitations of the hammers in the mill and also the size limitations of the raw domestic refuse prior to milling.

As an item of concern, a sieve analysis was run on the raw, un-milled refuse. When an 8 inch particle size was needed for the last pit, it was very difficult to try and obtain 70 percent passing or 30 percent retained on an 8 inch screen. It wasn't known whether this problem was caused by the hammer setting inside the mills or whether the size limitation was caused by the raw incoming refuse. As a result, a test was run on the raw refuse and it was found that the raw refuse itself, without even milling, would not meet the criteria of 30 percent material retained on an 8 inch screen. The one sample run on the raw refuse indicated that 30 percent of the sample was larger (70% passing) than a 4-1/4 inch screen. See Figure A-6. With a normal gradation, it would then be impossible to get anything larger than what the raw refuse gradation is coming into the pulverizer unit. With the majority of the hammers removed from the mill, the largest size particle obtainable was used for Pit #4. A 6 inch particle size was used for the top lift.

Figure A-2 for Pit #1 indicates that the top lift had 70 percent passing a 2-1/2 inch sieve. However, the lower lifts in Pit #1, lifts one through 4, varied in size from approximately 3-1/4 inches to 4-1/2 inches at the 70 percent passing line. Pit #2 had a top lift of approximately 4-1/2 inch particle size with the lower lifts varying from 4-1/4 inches down to 2-3/4 inches particle size at the 70 percent passing line. See Figure A-3. Pit #3 also had a top lift of approximately 4-2/3 inch particle size with the lower lifts varying from 4-1/2 inches up to 6 inches approximately at the 70 percent passing line. See Figure A-4. Pit #4 had a top lift using a 6 inch particle size. This was the largest size particle obtainable with the Great Falls milling facility. However, it was not the hammers that limited the size of the refuse. It was the refuse coming through the mill. The hammers were removed from the mill, leaving only enough hammers to push the refuse through the mill. Still it was impossible to obtain the 8 inch particle size that was originally proposed. This limitation, of course, or restriction was caused by the incoming refuse and not by the mill. The lower lifts in Pit #4 varied from approximately 4 inches up to 5-1/2 inches in diameter at the 70 percent passing line. This would be the largest particle size in any of the four pits. See Figure A-5.

Actual field installation of the milled refuse was as follows: The John Deere backhoe spread the milled refuse in lifts approximately 18 inches in depth. Then the Traxcavator located in the pit would compact the refuse until it would not compact anymore, or until there was no indentation left by the tracks on the surface of the refuse. This required about six passes over the refuse with one track. Following completion of the installation of each load or approximately 65 cubic yards of refuse, measurements were made to determine the in-place wet density of the load. Knowing the weight of the delivered load of refuse and the volume of the compacted refuse in place, the wet density was determined. At attempt was made to maintain a wet density of approximately 1,000 pounds per cubic yard in place. In order to determine the volume, measurements were taken from a string line stretched across the pit from the top of the plywood forms on the sidewalls. The string line that

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was stretched across from top to top of the sidewalls was used as a measuring point and all measurements were taken down from specified locations on the string line. This was done for each 65 cubic yard load of refuse compacted in place. Using these figures, it was possible to determine the volume after each lift was placed in the pit. The wet density of the top lift of placed refuse had to be determined using surveying level data since the last lift always was above the top of the wooden side forms. Densities varied from approximately 770 pounds up to over 1,200 pounds per cubic yard for an average somewhere around 1,000 pounds per cubic yard for all the pits. A density of 1,000 pounds per cubic yard was probably in excess of what most landfill operations accomplish in Montana. Greater compactive effort may be used in areas where land is more scarce, but in Montana where land is more readily available, there is generally less compactive effort applied to the waste.

To measure settlement that occurred within the lower portions of the pit, steel discs two feet in diameter were installed approximately four to five feet above the bottom of the pit. This was to provide for the top foot to 1-1/2 foot of refuse to be displaced by wind velocities throughout the two-year study period. With these plates installed below the surface, a determination could be made as to the amount of settlement taking place in the different pits throughout the period. The 1/4 inch plate metal discs were installed four per pit at the locations given in Figure A-1 in the back of this report.

Following completion of the refuse placement operation in each pit, holes were drilled back down to the surface of these metal discs and 4 inch diameter pipe was installed over the steel plates. This was to allow for access to the top of the metal discs throughout the project period. An attempt was made to dig through the compacted refuse by hand which proved almost impossible. A gasoline powered fence post auger was used to carefully dig down through the refuse to the metal discs. Then the holes were cleaned out by hand and the 4 inch diameter pipes installed for access to the tops of the metal plates. Caps were then installed on top of the pipes to prevent any refuse from blowing inside the access pipes causing errors in our settlement readings.

Following completion of the placement of the refuse and the installation of these plates, the pits were covered with plastic to prevent the refuse from blowing and being displaced prior to installation of the fenced enclosure. The fencing enclosed the four sides of each pit allowing for a three foot buffer area on the sides of each pit and a four foot buffer area on the ends of each pit. These areas were used to collect the refuse that was displaced by the wind. The weight of this displaced refuse was recorded during the monitoring stage of the data collection phase of this project.

A 1/2 inch galvanized mesh fencing material installed around the periphery of each pit confined the 1/2 inch or larger material to the pit area. Anything smaller than 1/2 inch could get through the fence and be blown away. Each fenced enclosure had an access gate into each test pit.

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Originally, the area over the top of each test pit was to be enclosed with a chicken wire mesh to prevent the refuse from soaring straight up out of the pit and away from the area. However, this top covering was eliminated to allow for bird access to the area. One of the items noted in the project was whether one size of material was attractive to more bird activity than the other.

DATA COLLECTION AND FIELD MONITORING

Previous mention has been made in this report of the sieve tests that were conducted during the placement of the refuse material in the test pits. Also, moisture tests and density tests were taken during the same period of refuse placement. In addition to the test data recorded on the initial construction phase of the project, additional tests were performed as the project progressed to determine different parameters. As mentioned before, settlement determinations were made on the test plates installed on the interior of each test pit. Also, elevations checks were made on the test pit surfaces on a periodic basis to determine if settlement took place on the surface of the pit. However, any displacement of the material caused by the wind also lowered the top working surface of the pit and, therefore, it was difficult to determine whether settlement took place on the surface or whether the material was actually displaced due to wind. However, as time progressed and the top surface built up a scum type layer preventing wind displacement of the material, it was possible to determine if settlement took place due to deterioration of the pit itself. An attempt was made to correlate displacement of the milled refuse in the test pits with wind velocity versus particle size. Other measurements in regard to fly, rodent activity, and bird activity, were made in addition to those tests mentioned above.

A comparison was made to determine the number of flies attracted to each plot to see if the different particle size material could be correlated with fly activity. A Scudder Grille was used as a means to count fly populations.

Fly grills are widely used in modern evaluation of fly populations. They are faster than baited trap or fly cone surveys and give a highly valid picture of the fly situation. The fly grill depends upon the tendency of flies to rest on edges, and so it presents many attractive resting sites. The grill is constructed of 16 three-quarter inch wide by 24 inch long wooden slats equally spaced on a 24 inch by 24 inch frame. The grill is placed over natural attractants (garbage, manure, etc.) and the number of flies landing on the grill during a 30 second interval is tabulated. When the grill is put down, the flies are somewhat disturbed and fly upward a short distance. When all is again quiet, they come back down, alighting on the grill instead of the attractant. Record is made of the total number of flies. A minimum of 10 counts is made in each area sampled, and the 5 highest counts are recorded on the grill record.

Rodent activity was checked in an attempt to correlate it with the size of the milled refuse. Since each test plot was fenced, two small 6 inch diameter access holes were cut in the fencing on the northeast and southwest

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sides of each test plot. This allowed the rodents to gain access to the area. Rats have never been observed in the Great Falls area, but gophers and field mice are common. To ascertain the rodent species, snap traps were set in each pit area along the fences and adjacent to the fence access holes. Also box traps were used, two per pit, for catching field mice to correlate numbers with particle sizes of refuse.

Bird activity was monitored for each test pit. During each visit to the site, bird activity was noted in and around each test plot. The test pit areas were not enclosed on the top to allow for bird access to the refuse.

Analysis of wind effects on the compacted refuse continued throughout the project period. Measurements of wind correlated with weights of refuse displaced was critical in the early stages of the project following material placement in the test pits. If the strongest wind encountered throughout the test period would have been recorded on the first day of the study, subsequent displacement of any refuse may not have occurred. All wind displaced material was collected and weighed at regular intervals.

Wind direction and velocity data recorded by the U.S. Weather Bureau at Great Falls was used for this study. The cost of purchasing and installing weather recording equipment on site was prohibitive. However, the data collected at the weather station location should be reprsentative of the test pit location.

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The enclosure around the test cells somewhat affected the wind currents in the test plots as would any type of obstruction in the area. However, it was impossible to determine any pattern to these currents. Even drifting snow within the pit areas did not indicate any specific patterns of wind current development.

Temperature and precipitation data was available from the U.S. Weather Bureau in Great Falls.

The Data Monitoring Schedule was as follows:

Refuse Displacement by Wind:

2 times/day for 0 to 12th day.
3 times/week for 13th to 31st day.
1 time/week for 5 additional months
1 time/month for remaining project refuse.

Settlement in Test Pits:

Discs Below Surface:

Once per month for first six months and every two months for remainder of project period.

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Surface Elevation Checks:

Once/month first four months. Once every two months thereafter.

Fly Counts:

Once/week from May through September for first year.
Once/month from May through June 30th for second year.

Rodent Trapping:

Same as fly counts.

Bird Activity:

Once/month from May-September.
Once every two months from October to April for project period.

SECTION 4

RESULTS OF TESTS AND FIELD OBSERVATIONS

GENERAL

On November 4, 1978, prior to completion of the fenced enclosures, wind gusts in excess of 80 mph fanned a fire at the City landfill site and wind-carried cinders started a fire in test pit #3. The fire destroyed the pit and any chances to obtain any future test data from it. Pit #3 was, therefore, eliminated from the project work.

On November 29, 1978, the test pits were completed with the fencing installed. The plastic covering that had been installed over the compacted refuse in the pits was removed. On December 1, 1978, a snow storm covered the test pits with a blanket of snow that was to increase with later storms. As one of our worst winters in history continued to drop snow over the area, windy conditions proved to have little effect on the pits in regard to displacing material. Windy periods caused a heavy crust to develop on the snow over the test pits and this crust or snow cover was to remain throughout the entire winter to about the middle of March when the snow melted.

The winter (1978-1979) weather had a detrimental affect on the parameters that were being measured at the test pits during the winter months. There was no wind displacement of the milled refuse during those periods when the snow cover existed over all the pits. Since the ground was frozen and also the compacted refuse in the pits was in an extremely cold condition, there appeared to be little settlement taking place within the pits. With the exception of some mice, there were no rodents, flies, birds, or wildlife attracted to any of the pits during these months. Following the first spring thaw in March when the snow melted, we experienced some rain in the area which also kept the pits in a dampened condition. This also affected the parameters that were being measured in the field. By mid-June it was obvious that something was going to have to be done to the refuse in the pits to loosen the surface bonding action that was taking place. The wind, rain and snowfall had helped to develop this bonding action that occurred on the surface of the milled refuse. It was determined at that time that the surface should be scarified on these pits or the refuse would not be subject to displacement by the wind. Wind displacement of the refuse was one of the parameters that was important to this study. As a result, a roto-tiller was used to try to effectively break up this top layer of bonded refuse on the surface of all the pits. The intent was to loosen up the surface to try and get some correlation between the wind and different particle sizes in the different pits. A discussion of the results of the data collected follows.

RESULTS

One of the parameters measured prior to placing the solid waste in the test pits was the composition of the raw solid waste. The composition of the raw solid waste as sampled for each test pit is shown in Table A-1 in the Appendix. The category for "Ash, Rocks and Dirt" was included under "Fines" since the material was too small to separate from other Fines. Grass cuttings were also included under Fines except for in pit #1 where an attempt was made to place it under Garden Waste. The average composition in percent by weight shown represented the typical composition of municipal waste for the Great Falls area as would be received in the fall of the year.

The Table also indicated for comparison purposes only, data from the Proceedings of the 1970 National Incinerator Conference and the Land Disposal Project for Boone County Field Site, Walton, Kentucky. With the data modified to include the same parameters, the Great Falls data is within statistically sound ranges. Our metal content was slightly higher than the other studies revealed, but this was due to one sample being high. There is a general indication that the refuse used in the test pits was similar to that produced by other areas.

Table A-2 in the Appendix indicates that field densities of the compacted refuse in each pit and also indicates the moisture content by dry weight of the refuse that was placed in each pit. The densities of these lifts vary from 833 pounds per cubic yard up to 1,364 pounds per cubic yard, with overall densities of 1,117; 991; and 987 pounds per cubic yard for pits 1, 2 and 4 respectively. This compared closely to our goal of 1,000 pounds per cubic yard. Pit #3 was omitted from the data determination due to the fire which destroyed the pit as previously mentioned.

The dry weight moisture contents varied from 13.2 to 32.01 percent for the different lifts with the average being 19.62, 20.85, and 21.19 percent for pits 1, 2 and 4 respectively. Normal moisture contents for municipal refuse vary from approximately 20 percent up to 60 percent so these percentiles in Great Falls would be on the low side of this range.

One of the goals of this project was to determine the affect of wind velocities on the displacement of milled refuse. The amount of refuse that was displaced was monitored as per the Data Monitoring Schedule previously given. The refuse collected was weighed for each pit.

Each month weather records were obtained from the weather bureau indicating peak wind velocities and average wind velocities for the entire month. The weather station is located at the International Airport west of Great Falls. The ground elevation of the weather station facilities is 3,662 feet above sea level. The elevation of the site is approximately 3,380 feet above sea level. Since the site is located at approximately the same elevation as the weather recording station and since there are no physical obstructions between the two facilities, there should be a correlation between the weather data from the forecasting office and the weather experienced at the test pit site.

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The weather bureau recording station collects data on wind each day. They record the time of the peak wind gust that lasts for just an instant. They also record the time of the fastest sustained wind that occurs over a one minute period. The meteorologist at the weather bureau in Great Falls indicated it would be unlikely that the instantaneous wind gust recorded at the weather station would occur with the same intensity at the milled refuse test plot. He indicated that it would be more likely for the one minute sustained peak wind to occur at both places. The one minute sustained peak wind recordings were used for wind data representative of the milled refuse test plot site wind.

The field data collected included the weight of the refuse displaced by the wind at each test pit for each observation period. The weather data indicated the peak winds experienced at the test pits for the same observation periods. Using the combined data, an analysis was made to determine if there was a correlation between the displaced refuse and the wind velocity.

Weed growth on the pit surfaces was noted during May of 1980. By June the weed growth was noticeable in all pits with most of the growth in Pit #1 and the least in Pit #4. By July the weed growth was so extensive that wind displacement of any refuse from the pit surfaces was negligible. The material displaced during July was not measurable so those readings were eliminated from the data used herein.

Points were plotted showing the weight of the displaced refuse corresponding to the one minute sustained wind velocity recorded for a given period of time for each test pit. This plotting was to determine if any correlation existed between the amount of refuse displaced and the velocity of wind experienced during that period. Figure A-7 in the Appendix of this report shows the data as plotted. Four different methods were checked for determining a representative curve that would provide the best fit for the data as shown. The data was checked using the linear regression method, exponential curves, logarithmic curves, and power curves to determine which type of curve would best fit the data collected. The coefficient of determination was calculated for each different method of curve fitting to determine which curve represented the plotted data the best. For pits #1 and #4, a power curve was the best fit for the data collected. For pit #2 the exponential curve fit the data best. The coefficient of determination indicated that because the data for the pits varied over such a wide range, the coefficient of determination was very low. This indicates that the curves developed were an indication more than an actual representation of the data plotted. The data did indicate that the larger the particle was, the more it tended to be displaced or blown away. Figure A-8 shows the number of field samples collected for each range of weight for the material displaced at each pit. The samples collected over the data collection phase of this project indicated that the larger particle sizes on the surface of pit #4 were displaced in a greater amount by weight than were the smaller particle sizes on pit #1. It was then concluded that the larger the milled particle size, the greater the weight of material displaced for a given wind velocity. Weight-wise, less material is displaced by wind in the smaller particle size of milled refuse.

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The curve data plotted in Figure A-7 indicates a considerable difference exists between pit #1 and pit #2. Pit #1 with a surface particle size of 2.4 inches at the 70 percent passing line compares to pit #2 at 4.7 inches particle size on the surface. Refer to Figures A-2 and A-3 for curve data. For a 40 mph sustained peak wind, the displacement of the smaller material in pit #1 totaled an average of 1.2 pounds compared to 2.6 pounds of the larger material in pit #2. For a 50 mph wind, the weight of material displaced in pit #2 was more than three times the weight of material displaced in pit #1. The curve data clearly indicates that the smaller the size of the milled refuse particle, the lower the wind displacement of the material on a weight basis. In an area where wind displacement is a problem, it is advisable to grind or pulverize the refuse to a small particle size prior to disposal. A small particle size means that 70 percent of the milled refuse will pass through a screen having square openings, 2.4 inches on each side. Refer to Figure A-2 to the curve for the fifth or top lift. The gradation of this top lift indicates that 40 percent of the sample passed a 1.0 inch mesh screen, (one inch on each side of square openings), 70 percent passed the 2.4 inch and 100 percent passed the 8.0 inch screen.

One of the parameters under study on this project is the determination of the amount of differential settlement that occurs in each test pit with correlation to particle size. Table A-3 in the Appendix of this report indicates the changes in the surface elevations of the test pits and also the elevations of the metal plates that were installed approximately two feet below the surface of each test pit. Non-pertinent interim field data recorded was eliminated here for clarity purposes. The elevations taken on the surfaces of the pits varied depending upon whether material had been displaced from that point or added to that point of measurement. The test plates down inside each test pit were not affected by the displaced material on the surface of the test pit. Therefore, the test plates were a good indication of whether settlement was taking place in the interior of each of the test pits. There were four test plates located in each test pit at a depth approximately two to three feet below the surface of the compacted refuse.

As soon as the solid waste was compacted in place at the end of November, 1978, inclement weather became a problem. As previously mentioned, snowfall covered the ground starting around December 1st and remained until the middle of March before it actually melted and exposed the surface of the test pits. Following that spring thaw, the area experienced a rainy season which kept the surface of the pits in a dampened condition until the end of May. A bonding layer or a scum had built up on the surface of the test pits by this time and it was obvious that the milled refuse was not going to be displaced a great deal by any wind that would occur. It was at this time that the decision was made to loosen up the bonded surfaces on the pits by scarifying the area. This action was necessary to attain any wind displacement field data and the surface settlement data was of secondary concern. After roto-tilling the pit surfaces, the elevations of the check points on the surfaces of each pit were re-determined and again monitored to determine if settlement was actually taking place. The pit surfaces were roto-tilled on June 14, 1979.

In almost all cases the elevations of the surface check points decreased. It is difficult to know whether the decrease was caused by settlement of the material, deterioration of the material or the displacement of the refuse on the surface of the pit. However, our elevation data on the test plates indicates a general trend that little settlement has occurred down inside the interior of the test pits. See Table A-3. In test pit #1, the test plates located down inside the interior of the test pit settled from 0 to 0.02 of a foot or a maximum of 1/4 inch settlement occurred. In test pit #2, the settlement varied from 0.01 to 0.02 of a foot or a maximim of 1/4 inch of settlement. In test pit #4, the maximum settlement was 0.03 to 0.06 of a foot or approximately 3/4 inch. The accuracy of standard surveying methods were limited here to $\pm$ 1/8 inch.

In conclusion, the settlement on the internal portions of the pit was very small during the 20 months data collection phase of the project. The extremely cold condition of the pits during the winter months of the project probably slowed deterioration of the milled refuse materials. Deterioration probably didn't even begin until sometime in April of 1979. Deterioration probably slowed again during the winter of 1979-1980, resulting in a total of 14 months when the pit interior was not frozen and deterioration of the milled refuse could take place.

Decomposition of landfills depends on the permeability of cover material, depth of burial and rainfall, moisture content and putrescibility of the refuse, particle size, and degree of compaction. The refuse decomposes slowly in most landfills through the anaerobic process of decomposition. Microorganisms of the soil and refuse are responsible for this decomposition resulting in end products of gases and humus material. Methane and carbon dioxide are the principal gases produced during the process of degradation of refuse in a fill.

Gas production is an indication of the extent of decomposition that takes place. Research data by Chian and DeWalle* on the "Effect of Moisture Regimes and Temperature on MSW Stabilization" indicates the effect of different environmental variables on solid waste. Their findings indicate that the higher the moisture content, the greater the deterioration of the waste. Also, the smaller the particle size, the greater the deterioration. Increasing the density of solid waste tends to decrease the gas production (deterioration) according to the mentioned report possibly because of a decrease in the effective surface area exposed to enzymatic hydrolysis. Lowering the temperature of the milled refuse also decreases the deterioration rate.

In the Great Falls test plots, the deterioration rate was slow. The reason being, based on the above report findings, the milled refuse was relatively dry, the particle sizes were small, the refuse was quite dense at 987 pounds per cubic yard and the winter ground temperatures were below freezing for approximately four months during a normal year.

*Chian, Edward S. K., and Foppe B. DeWalle. "Effects of Moisture Regimes and Temperature on MSW Stabilization", Proceedings of the Fifth Annual Research Symposium on Municipal Solid Waste: Land Disposal, U.S. Environmental Protection Agency, EPA-600/9-79-23a, pp. 32-40.

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Actual settlement of the compacted refuse in the interior of the test pits was so small that a settlement trend could not be correlated with the particle size of the refuse. Surface settlement or displacement of the refuse (whichever occurred is undeterminable) averaged 0.18 of a foot for Pit #2 and 0.13 of a foot for Pits #1 and #4. No correlation could be made here either with particle size of the solid waste. In conclusion then, based on the 20 months of data monitored at the Great Falls test sites where little settlement actually occurred, no correlation could be made between particle size of the material and settlement characteristics.

Fly counts were taken on a regular basis once a week from May through September during 1979 and from May through June in 1980. Fly counts ceased through the winter months and then continued again from May through the end of the project period. Throughout the project period, no fly activity developed at the test pits. A long snowy winter during 1979 - 1980, combined with a wet spring with a lot of precipitation helped to develop a bonding layer on top of the surface of the test pits. When the surface dried, the paper mache-like material was apparently not attractive to any fly population and did not support their growth.

The scum layer or surface deterioration of the refuse in the pits discouraged the propagation or attraction of flies to the area. During scheduled visits to the site, it was noted that a few wasps were present during one visit and a small gnat was noted in the area. The sanitary landfill site, located approximately 1/4 mile away, experiences nuisance fly population at times. However, throughout the project period, fly populations were not encountered at the test pit site.

If the air temperatures had remained warm and the weather dry following completion of the installation of the refuse in the pits, a nuisance fly population might have developed at the test site. With the onset of inclement weather that occurred immediately following installation of the refuse in the test pits and the subsequent formation of a surface bonding layer on the pits, insects were not attracted to the area at any time.

A Scudder Grill was used to count flies on each pit. However, when the grill was used to determine the fly populations on the pits, it indicated that there were no flies in the area. It was common to visit the site and collect all the test data and maybe only see one insect flying through the area.

It was concluded from this information that densely compacted milled refuse that has been covered with snow throughout the winter and has received a considerable amount of precipitation in the spring, develops a bonding layer that will not attract or support a fly population.

To determine the rodent population in each pit, four six-inch access holes were cut in the fencing material enclosing each pit site. On the inside of each pit we located a rat trap adjacent to each of the holes cut in the fencing material. At the center of the east side and the west side of each test pit a Ketch-All box trap was placed which was an effective trap for holding up to 15 mice at one time. The traps were checked once a week from

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May through September the first year and from May through June the second year. Table A-4 in the Appendix of this report indicates the summary of the number of mice caught in the traps. There were no other types of rodents caught in any of the traps or sighted in the area. Rats were not sighted at the test area and have not been sighted at the local landfill site which is approximately 1/4 of a mile away from the test pit site. However, field mice seemed to exist in the area and feed on the material at the test pit site.

Test pit #3, which was abandoned due to a fire in the pit, was previously dug up in order to extinguish the flames in the burning material. As a result, the refuse in test pit #3 remained in a loose, uncompacted state compared to the densely compacted refuse in pits 1, 2 and 4. A trend was noted during the winter months when snow cover revealed mice runs on the ground. There was some mice activity in the area; the mice were bypassing pits 1, 2 and 4 to use or occupy pit #3. There the refuse was uncompacted and the mice could get access to the internal portion of the pit. Traps were set starting in May of 1979 using both box traps and spring snap traps. Mice were caught continually throughout the project period, excluding the winter months. The mice activity was greater at first and slowed throughout the summer and fall of 1979 and increased in June and July of 1980. Approximately 29 mice were caught in one week at the beginning of May, 1979. By September, the count dropped to only one to six mice a week. During a five week period in June and July of 1980, 38 mice were caught. See Table A-4.

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There doesn't appear to be a correlation between the mice activity and different particle sizes in pits 1, 2 and 4. The total catch for the monitoring period amounted to 92, 57, and 85 mice respectively in pits 1, 2 and 4 for those months monitored. Since pit #1 had the smallest material at the surface and pit #4 had the largest material at the surface, it appeared that there was no correlation between mice activity and the different sizes of material. However, the amount of compaction given to the refuse affected the mice activity as indicated by pit #3. It appears that refuse that is not compacted in place will attract more mice than will refuse that is well compacted. It probably should be noted here again that the refuse in pits 1, 2 and 4 was compacted to approximately 1,000 pounds per cubic yard which was quite dense compared to the refuse density of many landfills. When refuse is compacted to a density of 1,000 pounds per cubic yard, it is extremely dense and quite hard on the surface of the refuse. This is probably the reason the mice were more interested in the loosely compacted refuse that they were in the well compacted refuse.

Bird activity in the area was essentially non-existent as recorded during visits to the site. In the fall of 1978, there were numerous seagulls in the area that would feed on the refuse during the placement operation. However, once the material was in place and compacted, it appeared that the birds were no longer interested in the refuse and bird activity in the area all but ceased from then on. One sparrow was caught in a spring trap in pit #4 during the month of August. Also one hawk was noted perched on the west side of pit #4 during the month of June. During August, a dove was noted sitting on the fence at pit #1. These birds were not feeding on the refuse but were either resting or attempting to eat the cheese that was

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baited in the traps used for catching rodents at the site. In conclusion then, bird activity cannot be correlated with the different particle sizes of milled refuse in the pits. It appears that bird activity is minimal when milled refuse is compacted to a density of 1,000 pounds per cubic yard.

Some additional things that were noted during visits to the site are of interest. In the buffer zones around each pit, weed growth started to appear during the month of July of 1979, eight months after material placement. The surfaces of pits 1, 2 and 4 were roto-tilled or broken up in June of 1979. However, pit #3 which remained undistrubed because of the fire in that pit, started to support weed growth in the solid waste. In late July of 1979, the weed growth appeared in pit #3 on the surface of the milled solid waste. This weed growth was not extensive but it was an indication that milled refuse will support vegetation growth. The weed growth appeared in May of 1980 on Pits 1, 2 and 4 and continued to flourish on the pit surface areas through the end of the project period or July, 1980. This growth appeared 11 months after the pit surfaces were scarified and as soon as the growing season began. Vegetation growth in milled refuse was not a parameter under study in this project.

6-1/2"

In summary, it can be stated that there was no correlation between milled refuse particle size and fly counts, rodent activity or bird activity. There also was no correlation between particle size and settlement or degradation of the refuse. It does appear that once the wind reaches a one minute sustained velocity of 10 mph that all sizes of the milled refuse will be displaced. There does appear to be a correlation between weight of milled refuse displaced and the particle size of the refuse once the wind velocity has reached the point where it will displace the material. The larger the particle size, the greater the weight of the material displaced for a given wind velocity.

This research project was initiated with the overall objectives of determining the affects of milled refuse particle size on landfilled solid waste. The results of the study do indicate that the smaller particle size of milled refuse does have one advantage in regard to wind displacement. Less material is displaced on a weight basis for smaller particle sized material than for larger particle sized milled refuse. However, the two-year study was unable to show any relationship between particle size of milled refuse and settlement characteristics, fly, rodent, or bird activity. It did indicate that a milled refuse material compacted to a density of 1,000 pounds per cubic yard provided a very dense fill that did not attract flies and birds. Field mice even preferred less dense material. The surface of the pits developed a scum layer during a wet winter season and it took only six months to develop. This paper mache-like scum layer helped to deter the fly, bird and rodent activity. This bonding of the surface layer also helped to deter the wind displacement of the material. It should be noted that even though we could not establish a correlation between particle size and settlement characteristics of the milled refuse, this does not mean that a correlation does not exist. The data collected indicated that insufficient evidence was available to date, because of minimal settlement of the test pit material, to form any definite conclusions in regard to settlement.

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One note of caution should be mentioned here for anyone considering requiring that refuse be milled to a given particle size. It will be difficult to consistently mill any refuse to a preferred particle size using vertical shaft mills. The sieve analyses indicated that when grinding the refuse to the smaller particle sizes, the units installed in Great Falls would not produce one consistent size particle. The continual increase in particle size is caused by the normal wear of the hammers in these mills. When milling the larger particle sizes of refuse, the particle size varies with the particle size distribution of the incoming raw waste. Hammer wear would be experienced to some degree on any brand of shredding equipment and is not unique to those similar to the Great Falls milling units. It is possible that a change in the design of some grinding mills may be required if a limitation is to be placed on the size of particles that are to be produced on a continual basis. Anyone setting limits on particle sizes for milled refuse should take into account the limitations of the milling equipment available on the market.

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TABLE A-1 REFUSE COMPOSITION COMPARISONS

Sample Location	Total Weight Separated (pounds)	COMPONENT-PERCENT BY WET WEIGHT								
		Food Waste	Garden Waste	Paper	Rubber, Leather, and Textiles	Wood	Metal	Glass	Plastic	Ash, Rock, Dirt, Fines and Misc.
Pit #1	98.4	8.1	10.4	55.8	9.6	0.2	5.4	6.8	2.7	1.0
Pit #2	136.9	9.4	1.9	38.5	2.2	3.6	16.9	9.9	8.4	9.2
Pit #3	219.7	1.9	22.7	28.1	0.4	0.9	7.9	4.9	5.5	27.7
Pit #4	102.9	5.0	9.7	35.8	2.2	1.2	13.2	5.7	7.3	19.9
Avg. of all pits	---	6.1	11.2	39.6	3.6	1.5	10.8	6.8	6.0	14.4
Avg. of Pits *	---	8.2	Excluded	53.3	4.8	2.0	14.5	9.1	8.1	Excluded
1968 Annual Avg.	---	19.3	---	51.6	4.6	3.0	10.2	9.9	1.4	---
Boone Cnty. Kentucky +	---	4.5	9.2	49.2	10.3	4.1	9.2	7.1	Incl.w/ Rubber	6.3
Boone Cnty. w/o misc.	---	5.4	Excluded	58.3	12.2	4.9	10.9	8.4	Incl.w/ Rubber	Excluded

Grass included here for this test only.
Excluding garden waste, ash, rocks, dirt, fines and miscellaneous.
Estimated annual average National Refuse Composition on a yard waste-free and misc.-free basis - 1970 National Incinerator Conference Proceedings.
Land Disposal Project, Boone County Field Site, Walton, Kentucky, January, 1973.
Includes plastics.
Excludes ash, rock, dirt, fines and miscellaneous garden waste.

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TABLE A-2 DENSITY-MOISTURE SUMMARY SHEET

SAMPLE LOCATION	LIFT	DENSITY X LBS/C.Y.	OVERALL* DENSITY LBS/C.Y.	MOISTURE % BY DRY WEIGHT
Pit #1	1	879		14.76
	2	1099		19.21
	3	1104		31.23
	4	1128		17.93
	5 & 6	1364		14.95
TOTAL AVERAGE		1115	1117	19.62
Pit #2	1	835		22.48
	2	1260		13.20
	3	833		19.84
	4	1157		16.73
	5	935		32.01
TOTAL AVERAGE		1004	991	20.85
Pit #3 Destroyed by fire				
Pit #4	1	852		17.82
	2	1009		14.39
	3	1108		29.04
	4	1213		25.79
	5	1066		22.95
	6	862		17.12
TOTAL AVERAGE		1018	987	21.19

X Based on weight of refuse compacted in a field measured volume for each lift of placed refuse.

* Based on survey elevations taken on bottom of empty pit and top of final lift for volume determination. Total weight of all refuse in pit included in determination.

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TABLE A-3 SURFACE & TEST PLATE ELEVATIONS

OBSERVATION POINT	PIT NO. 1 DATE OF OBSERVATION 11/28/79	6/1/79	6/14/79 *	3/3/80	7/8/80
a	99.83	99.68	99.62	99.61	99.52
b	99.69	99.65	99.84	99.74	99.53
c	99.74	99.59	99.76	99.61	99.54
d	99.67	99.40	99.48	99.37	99.24
e	99.26	99.12	99.06	99.13	99.00
f	99.25	99.30	99.40	99.31	99.22
g	99.25	99.10	99.12	99.05	99.13
h	98.97	98.83	98.79	98.71	98.95
i	98.28	98.21	98.31	98.22	98.17
j	98.34	98.37	98.59	98.47	98.40
k	98.49	98.38	98.57	98.49	98.40
l	98.17	98.11	98.29	98.21	98.11
m	97.68	97.69	97.74	97.66	97.62
n	97.89	97.78	97.96	97.91	97.88
o	97.74	97.68	97.85	97.77	97.75
p	97.42	97.39	97.55	97.41	97.40
TEST PLATES					
NW	97.06				97.04
NE	96.76				96.76
SW	96.47				96.45
SE	96.26				96.29

*Pit surface roto-tilled on June 14, 1979.

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TABLE A-3 (continued)

OBSERVATION POINT	PIT NO. 2 DATE OF OBSERVATION 11/28/79	6/1/79	6/14/79 *	3/3/80	7/8/80
a	96.45	96.34	96.54	96.43	96.34
b	96.88	96.62	96.74	96.70	96.62
c	97.08	96.91	97.05	96.95	96.88
d	96.90	96.51	96.72	96.63	96.55
e	96.27	96.03	96.17	96.07	96.02
f	96.75	96.56	96.62	96.52	96.49
g	96.76	96.68	96.80	96.64	96.56
h	96.53	96.36	96.50	96.42	96.24
i	95.67	95.52	95.46	95.43	95.36
j	96.25	95.99	96.27	96.06	96.03
k	96.11	95.99	96.22	96.05	95.98
l	95.97	95.73	95.99	95.80	95.69
m	94.97	94.83	94.78	94.68	94.61
n	95.19	95.16	95.31	95.23	95.12
o	95.40	95.31	95.33	95.29	95.19
p	95.39	95.11	95.06	95.02	94.93
TEST PLATES					
NW	93.91				93.89
NE	93.89				93.88
SW	93.24				93.23
SE	93.03				93.02

*Pit surface roto-tilled on June 14, 1979.

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TABLE A-3 (continued)

OBSERVATION POINT	PIT NO. 4 DATE OF OBSERVATION 11/28/79	6/1/79	6/14/79 *	3/3/80	7/8/80
a	91.12	90.92	91.06	90.95	90.98
b	91.53	91.40	91.46	91.41	91.34
c	91.83	91.93	91.92	91.78	91.70
d	91.84	91.52	91.59	91.59	91.46
e	91.03	91.03	90.96	90.91	90.84
f	91.58	91.48	91.66	91.59	91.46
g	91.62	91.59	91.74	91.63	91.58
h	91.57	91.33	91.45	91.41	91.34
i	90.69	90.55	90.61	90.54	90.48
j	90.94	90.99	91.05	91.03	90.93
k	91.28	91.20	91.24	91.24	91.19
l	91.20	90.93	91.18	91.15	91.01
m	90.21	90.09	90.01	89.99	89.93
n	90.30	90.32	90.26	90.20	90.19
o	90.62	90.39	90.54	90.47	90.36
p	90.37	90.43	90.20	90.17	90.06
TEST PLATES					
NW	88.54				88.50
NE	88.71				88.68
SW	87.97				87.91
SE	88.03				88.00

*Pit surface roto-tilled on June 14, 1979.

TABLE A-4 FIELD MICE COUNTS

Date	Pits =	BOX TRAPS #1	#2	#4	SPRING SNAP TRAPS #1	#2	#4	TOTAL ALL TRAPS
5/14/79	Set Traps							
5/23/79		8	4	10	3	2	2	29
6/01/79		4	4	7	3	4	4	26
6/11/79		6	1	7	0	2	3	19
6/22/79		4	3	6	1	1	1	16
6/29/79		2	1	3	1	1	1	9
7/09/79		2	1	6	3	1	1	14
7/13/79		0	1	2	2	2	1	8
7/20/79		0	0	1	2	2	2	7
7/27/79		1	4	2	0	1	1	9
8/08/79		0	0	0	4	2	2	8
8/17/79		0	1	0	2	3	2	8
8/25/79		0	0	1	0	3	3	7
8/31/79		0	0	0	0	2	1	3
9/07/79		1	0	0	0	0	0	1
9/14/79		1	0	0	0	0	1	2
9/21/79		1	0	0	3	1	1	6
9/28/79		0	0	0	2	1	1	4
6/02/80		12	0	1	2	3	2	20
7/08/80		18	6	6	4	0	4	38
TOTALS:		60	26	52	32	31	33	234

Pit Totals: #1 = 92; #2 = 57; #4 = 85

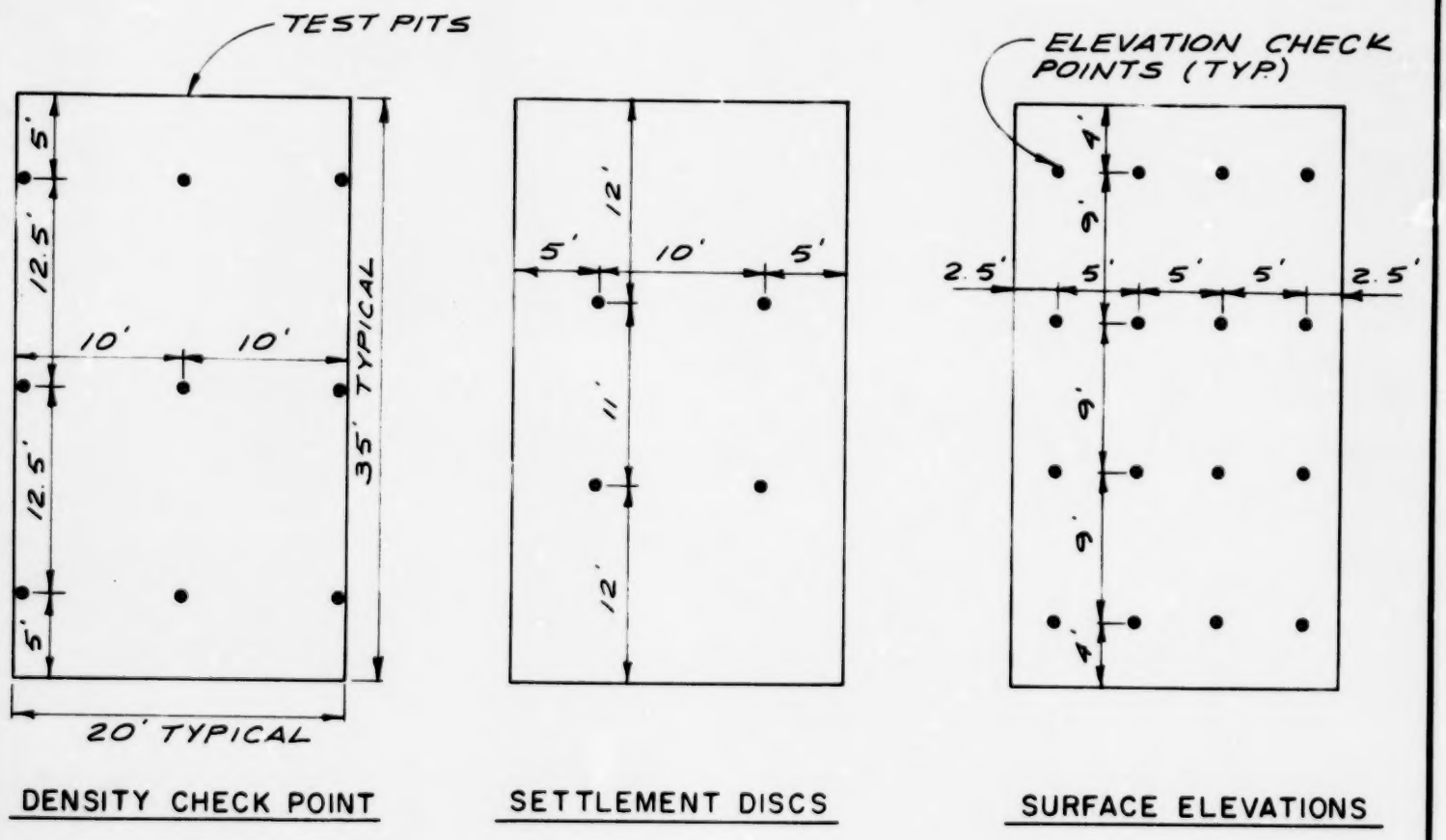

FIGURE A-1 ELEVATION CHECK POINTS

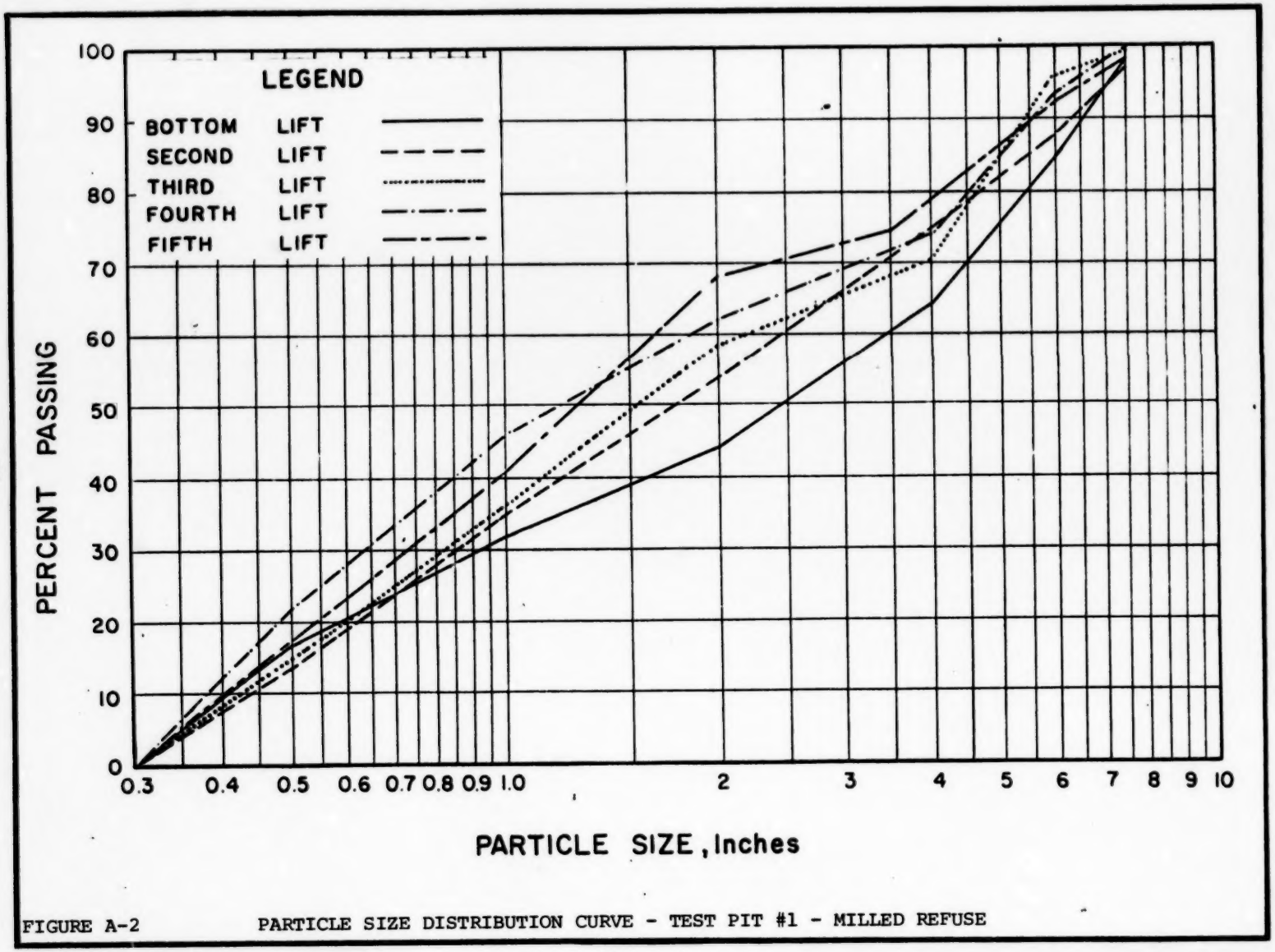

FIGURE A-2 PARTICLE SIZE DISTRIBUTION CURVE - TEST PIT #1 - MILLED REFUSE

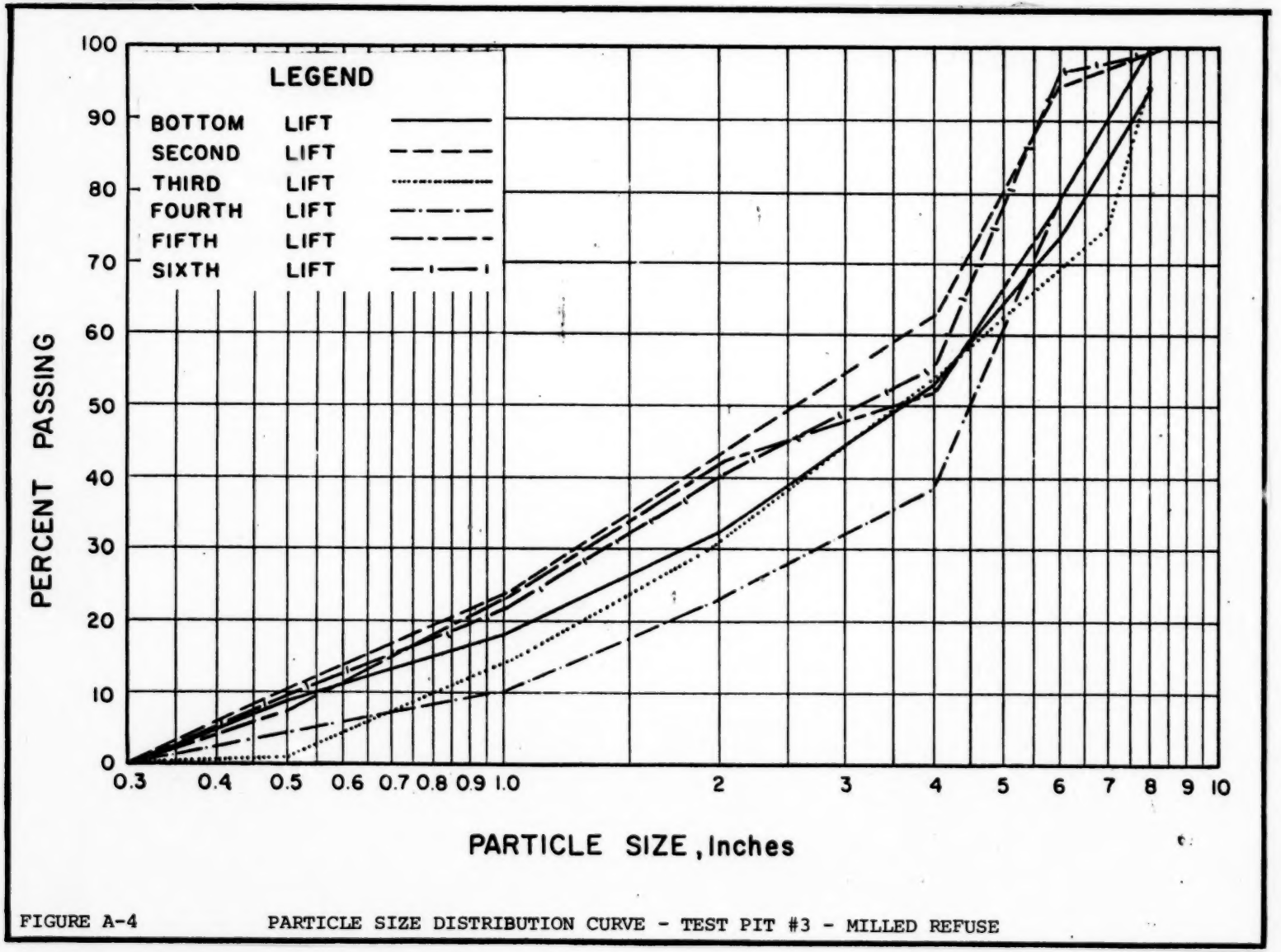

FIGURE A-4 PARTICLE SIZE DISTRIBUTION CURVE - TEST PIT #3 - MILLED REFUSE

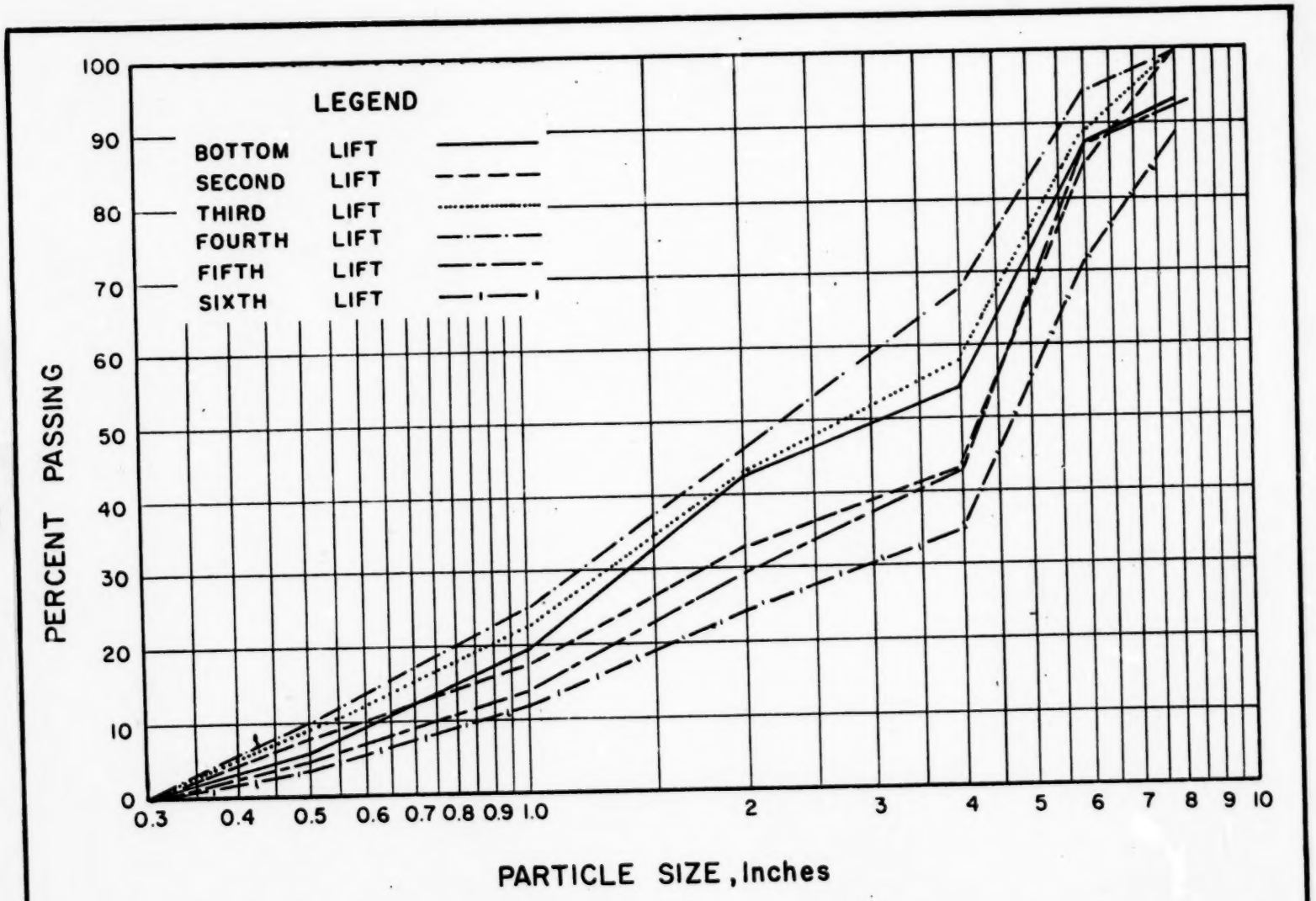

FIGURE A-5 PARTICLE SIZE DISTRIBUTION CURVE - TEST PIT #4 - MILLED REFUSE

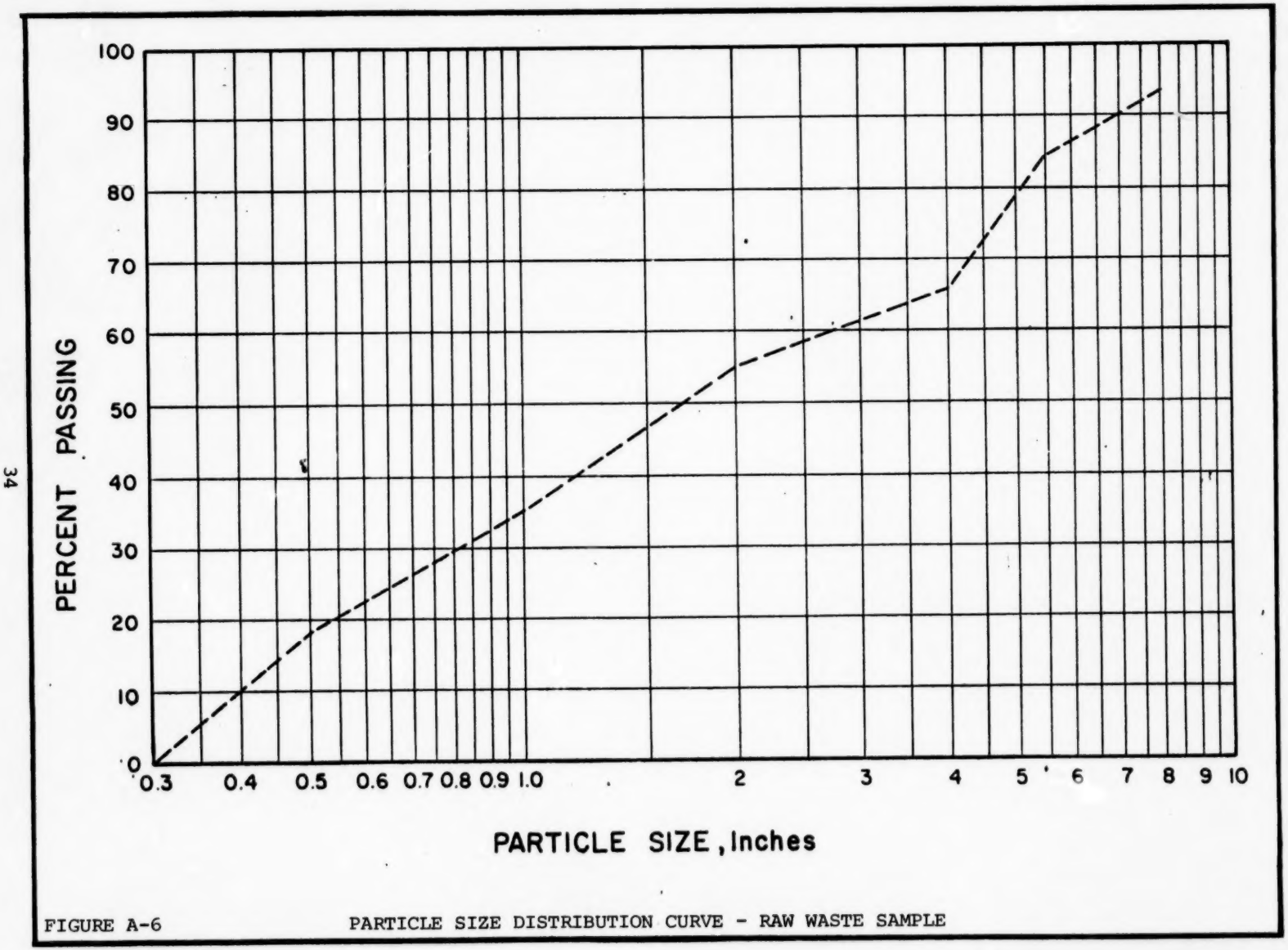

FIGURE A-6 PARTICLE SIZE DISTRIBUTION CURVE - RAW WASTE SAMPLE

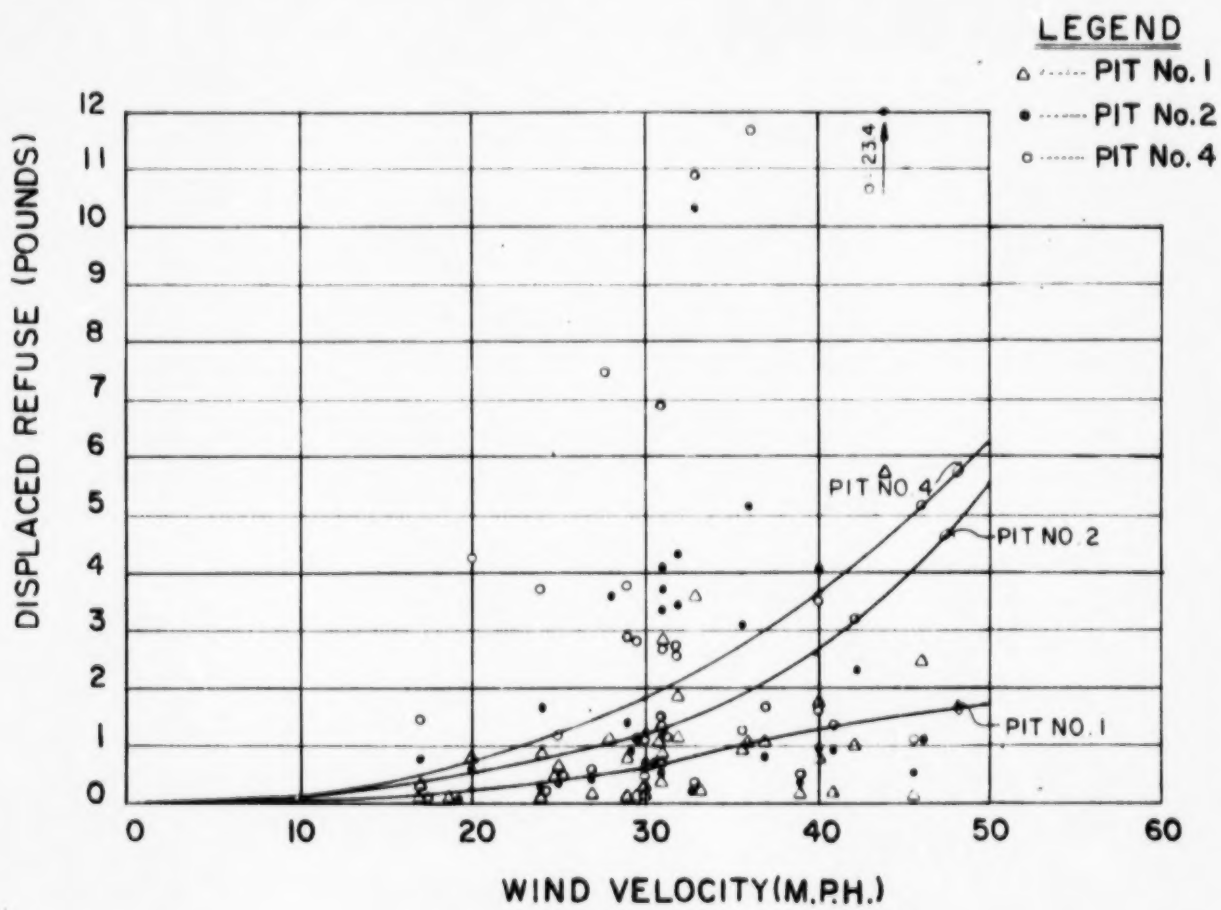

FIGURE A-7 WEIGHT OF DISPLACED REFUSE VERSUS WIND VELOCITY IN TEST PITS 1, 2 and 4

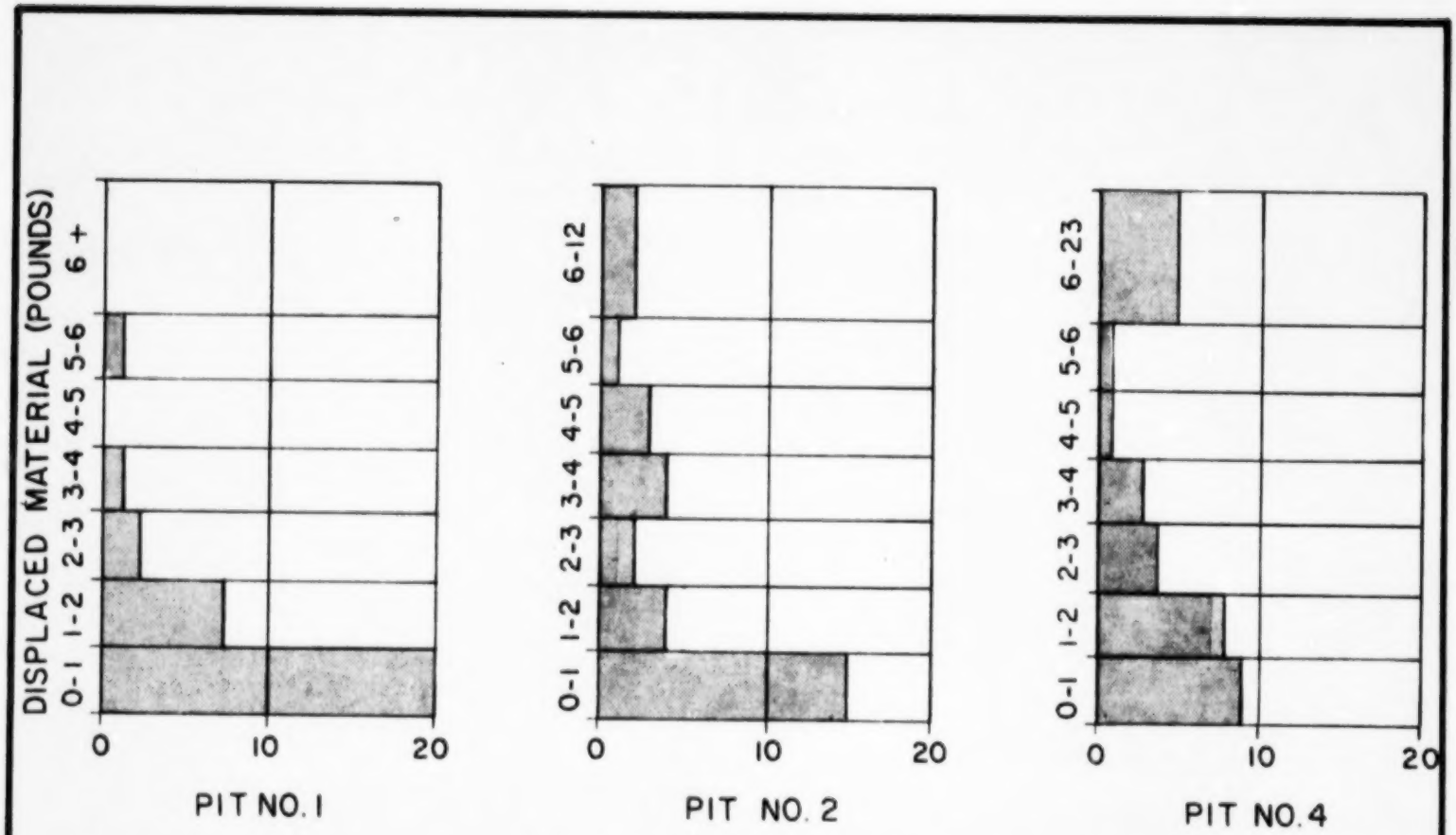
DISPLACED MATERIAL (POUNDS)
0-1 1-2 2-3 3-4 4-5 5-6 6 +
0 10 20
PIT NO. 1
0-1 1-2 2-3 3-4 4-5 5-6 6-12
0 10 20
PIT NO. 2
0-1 1-2 2-3 3-4 4-5 5-6 6-23
0 10 20
PIT NO. 4
NO. OF FIELD SAMPLES RECORDED FOR EACH RANGE OF WEIGHT DISPLACED

FIGURE A-8 WEIGHT OF DISPLACED REFUSE VERSUS NUMBER OF SAMPLES IN THAT RANGE - TEST PITS 1, 2 and 4

CONVERSION FACTORS

English to Metric

English Unit	Abbreviation	Multiplier	Abbreviation	Metric Unit
cubic foot	cf	28.32	l	liter
cubic inch	cu. in.	16.39	cu cm	cubic centimeter
		0.0164	l	liter
cubic yard	cy	0.765	cu m	cubic meter
		764.6	l	liter
foot (feet)	ft	0.305	m	meter(s)
gallon(s)	gal.	3.785	l	liter(s)
inch(es)	in.	2.54	cm	centimeter
mile	mi	1.609	km	kilometer
		1.609	m	meter
mile per hour	mp	1.609	kms/hr	kilometers per hour
pound(s)	lb	0.454	kg	kilogram
		453.6	g	grams
square foot	sq ft	0.0929	sq m	square meter
ton (short)	ton	907.2	kg	kilogram
		0.907	metric ton	metric ton
yard	yd	0.914	m	meter